DOCUMENT RESUME

ED 371 124 CE 066 430

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TITLE Draft Cognitive Skills Training Program for En-Route Air Traffic Controllers.
INSTITUTION Human Technology, Inc., McLean, VA.
PUB DATE 1 Jun 94
NOTE 74p.
PUB TYPE Reports - Evaluative/Feasibility (142)

EDRS PRICE MF01/PC03 Plus Postage.
DESCRIPTORS *Air Traffic Control; Behavioral Objectives; Competency Based Education; *Computer Assisted Instruction; *Job Skills; Lesson Plans; Postsecondary Education; *Skill Development; Standards; Student Evaluation; Task Analysis; *Thinking Skills; *Vocational Education

ABSTRACT

This document begins with a discussion of the cognitive task analysis (CTA) that was commissioned by the Federal Aviation Administration to identify the cognitive skills-related training needs of en-route air traffic controllers. Concluding the introductory section are a brief list of recommendations regarding the design of a training program based on the CTA results. The remainder of the document consists of a draft cognitive skills training program that is based on the findings of the CTA. The program consists of eight instructional blocks covering the following skill areas: acquisition and organization of sector information, short- and long-term planning, controller tasks, strategy selection, monitoring and situation awareness, data verification, workload reduction, and critical incident training. Each training block includes a lesson goal, estimate of the time required to complete the block, and lesson plan consisting of a series of objectives. Accompanying the objectives listed in the first five blocks are some or all of the following: conditions/instructional methods and media, note(s) to the instructor, student evaluation standards, and rationale. (MN)

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ED 371 124

DRAFT COGNITIVE SKILLS TRAINING PROGRAM FOR EN-ROUTE AIR TRAFFIC CONTROLLERS

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June 1, 1994

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ABSTRACT

The Federal Aviation Administration (FAA) has embarked on a major curriculum redesign effort to improve the training efficiency of en route air traffic controllers. The current training program takes too much time and has an insufficient pass rate. Moreover, graduates of the FAA academy are not sufficiently prepared for work in control centers.

Included in this redesign effort was a cognitive task analysis (CTA), representing a major research program conducted in several phases, to delineate the cognitive structures and processes supporting controller expertise. The CTA enabled the decomposition of this rich expertise so it can be transmitted more systematically to trainees, thus improving training quality and reducing training time.

The draft cognitive skills training program outlined here is based on the results of the cognitive task analysis. The proposed computer-based training program uses a model building/guided discovery approach, with limited air traffic control scenarios providing the context for assimilating the domain knowledge and skills characteristic of expertise.

This represents one of the first uses of CTA for the development of an entire redesign for the training of a complex high-performance task.

INTRODUCTION

The Cognitive Task Analysis. The cognitive task analysis (CTA) results and training implications are reported in detail elsewhere (Redding, 1992; Redding, Cannon & Lierman, 1991; ; Redding, Cannon & Seamster, 1992; Redding & Seamster, 1994; Redding et al., 1990, 1991; Seamster et al., 1992, 1993).

The CTA resulted in an integrated, comprehensive picture of controller expertise, including: an expert mental model (Figure 1), a task decomposition of the ATC job (Figure 2), controller strategies (for monitoring, planning, and workload management), a set of goals and means priorities, and critical cues of work overload.

Those results indicated that ATC expertise is best characterized by an efficient mental model combined with a rapid retrieval system for applying the knowledge when needed. The expert controller's mental model has a number of characteristics allowing for this efficiency. Importantly, it categorizes aircraft into sector traffic events, giving priority to aircraft altitude, location, and route in doing so. This allows the expert to work with more aircraft at a time, to better formulate a sector plan, and use fewer control actions and strategies to work with the aircraft.

The mental model derived from the CTA (Figure 1) provides the framework for more efficient training and learning, forming the basis for teaching all ATC knowledge and skills. The mental

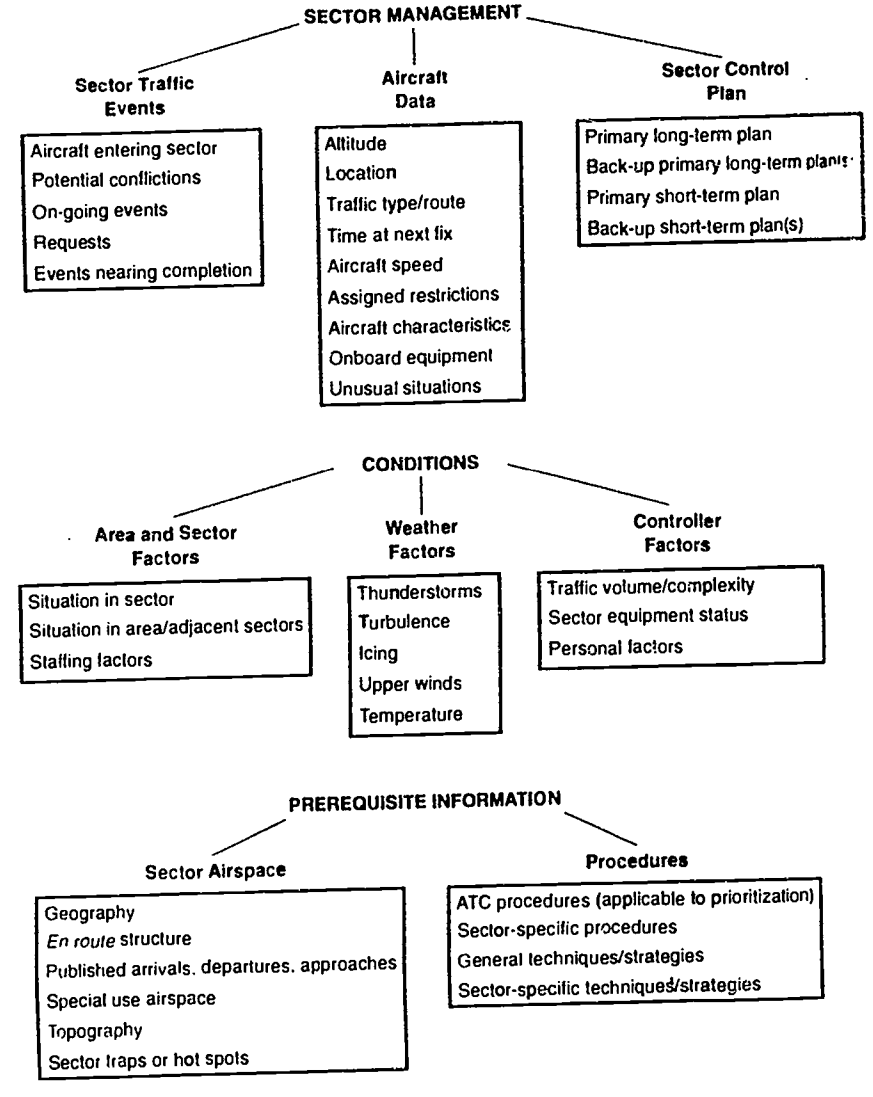

Figure 1 Expert mental model of *en route* air traffic control
(Source: Redding *et al.*, 1991)

Maintains situation awareness – Maintain understanding of current and projected positions of aircraft in the sector to determine events that require controller activities.
Develop and revise sector control plan – Develop and revise a plan for controlling the sector that is current, comprehensive, and that handles contingencies.
Resolve aircraft conflict – Evaluate potential conflicts and implement means to avoid them.
Reroute aircraft – Change aircraft routes in response to requests or situational considerations.
Manage arrivals – Establish sequence and routing of aircraft for arrival into an airport.
Manage departures – Maintain safe and efficient departure flows integrated with other sector traffic.
Manage overflights – Maintain safe and efficient overflights and integration of overflights with other sector traffic.
Receive handoff – Accept, delay, or deny handoffs.
Receive pointout – Assess and accept or decline a pointout from another controller.
Initiate handoff – Transfer aircraft radar identification and radio communications to the receiving controller.
Initiate pointout – Initiate and complete pointout of aircraft to the receiving conroller.
Issue advisory – Provide information update to a pilot or another controller.
Issues safety alert – Provide mandatory safety warning to a pilot.

Figure 2 The 13 key tasks of the *en route* air traffic controller
(Source: Seamster, *et al.*, 1993)

model implies that controller procedures should be taught by event type, with training emphasizing the integration of aircraft information into sector relevant groupings. This event-based approach includes training in the categorization of aircraft into event types and scanning for sector events. This type of scanning improves memory efficiency by organizing sector data into chunks of related information.

The CTA findings suggested the following general factors to be the most important for ATC expertise, roughly ranked in order of importance:

1. Situation awareness through effective monitoring/scanning techniques and mental model updating.
2. Effective mental model of the sector.
3. Use of workload management techniques and strategies.
4. Higher-level cognitive tasks rather than ATC procedures or behavioral activities.
5. Effective problem-space organization.
6. Effective long-term, advance planning.

The Training Program. The cognitive skills training program is based upon the CTA results. In order to provide scaffolding and guidance to students, instructional objectives are organized around the key characteristics and organizers of the expert models and strategies identified in the CTA. This does not mean

teaching novices to structure their models based on a fixed expert model. It may be preferable for students to develop their own rule systems and organizational structures. There may be a variety of viable mental models, with a model's effectiveness depending upon the cognitive profile of the learner. Moreover, certain aspects of novice models may be useful to students during the early stages of learning.

The training program thus reflects a model-building/guided discovery approach to instruction. Implicit in the learning exercises are the primary organizing principles characteristic of expertise. But the exercises allow students to construct their own specific models, algorithms, and rule systems. Instruction for each block begins by presenting only the most relevant stimulus patterns and/or knowledge categories related to the content area, facilitating the development of automaticity and skilled behavior. A "constraints" approach is used, whereby students are given limited control scenarios which allow them to see the underlying commonalities and predictable elements across various situations involving a particular task, event, problem, or task. Aspects of situations that are common to the particular task, event, or problem type are held constant, while other attributes are varied across scenarios.

The specific goals of the training program are to:

* Use the mental model as the organizational framework both for learning and for job performance.

* Provide instruction in monitoring and scanning

techniques that are most effective for maintaining situations awareness.

* Provide training in grouping aircraft into event types.

* Organize training around the 13 major controller tasks.

* Emphasize the Maintain Situation Awareness, and Develop and Revise Sector Control Plan tasks.

* Provide part-task training in task trigger recognition.

* Demonstrate and provide practice in multiple strategies for implementing each task subgoal.

* Provide instruction in recognition of workload level.

* Emphasize strategies for managing and reducing workload, particularly those which serve to simplify the situation.

* Provide differential training in short- vs. long-term planning.

The cognitive skills training module is organized into eight blocks, each containing a number of instructional objectives:

1. Mental Model Development (acquiring and organizing sector information)
2. Planning
3. Controller Tasks
4. Strategy Selection
5. Situation Awareness
(6. Data Verification)[1]
(7. Workload Reduction)
(8. Critical Incidents)

Because training sequencing should promote development of an effective mental model as the basis for organizing and acquiring domain knowledge as well as for maintaining situation awareness,

[1]In this draft, for Blocks 6-8 only the learning objectives are listed, because the lesson plans for those blocks have not yet been completed.

instruction begins with mental model development. In each stage of learning, the mental model guides and organizes learning activities and is elaborated and refined throughout training. Planning skills are then taught in relation to the mental model, followed by procedural knowledge. Once students have developed an effective mental model and have mastered basic planning and air traffic control tasks and skills, students practice situation awareness skills in relation to the mental model and controller task. Finally, students refine and extend their skills through training around critical or unusual incidents.

Instruction should be delivered in small chunks of related knowledge and skills, followed by simulation-based instruction and practice. The training-program uses this problem-based approach to training, with actual problems providing the context for assimilating basic domain knowledge. The traditional approach of providing knowledge application only <u>after</u> the completion of all classroom instruction makes it difficult for students to integrate the knowledge with real-time controlling skills.

The real-time, dynamic nature of ATC requires that simulator training begin as early as possible in instruction. For many of the Objectives, instruction begins with a brief classroom lecture, discussion, or demonstration. For others, instruction begins immediately with computer-based practice. Some objectives are amenable to classroom instruction while

others are best learned simply through student practice and experimentation. With a few exceptions, all of the objectives could be accomplished through workbook exercises, video demonstrations, etc. In most cases, scenarios could be presented in a workbook through a series of printouts showing the scenarios at various points in time.

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DRAFT COGNITIVE SKILLS TRAINING PROGRAM

BLOCK 1. ACQUIRING AND ORGANIZING SECTOR INFORMATION.

Lesson Goal: To develop efficient techniques for acquiring sector information and a mental model for organizing the information.

Time: ----- Days.

Lesson Plan

OBJECTIVE 1: Develop sector familiarity, and construct a spatial representation of the sector airspace.

Conditions/Instructional Methods and Media: Students will first be given a brief classroom lecture on sector airspace characteristics and the importance of each characteristic. Students will then be given a computerized three-dimensional representation of AeroCenter, and asked to plot (using a lightpen) key features of the sector airspace by drawing closed curves. Feedback will be provided by comparing the student's plottings with an expert representation, through an overlay of the two representations. This will be done for each airspace characteristic listed below. Finally, the computer will generate a comprehensive spatial representation that includes all the airspace characteristics, with each characteristic given a different graphic representation (e.g., different color codings, different lines, etc.). Students should be allowed to experiment by constructing various graphic representations of the airspace, and also to compare their constructions with those of other students by working the computer simulation in pairs.

Note: This lesson could also be taught using workbook exercises involving two-dimensional sector maps.

Standards

Identify lateral and vertical limits of key geographical aspects of the sector (sector boundaries, airport locations, NAVAID locations).

Identify key en-route structures.

Identify published arrivals, departures, and approach paths.

Identify special use airspace.

Identify key topography.

Identify sector traps or hot spots.

RATIONALE: The most fundamental aspect of ATC involves an understanding of the airspace. Thus, sector airspace is the first objective, with the key aspects of sector knowledge used as organizers for student model development. Development of a mental model for the sector airspace is facilitated by constructing visual-spatial representations.

OBJECTIVE 2: Use effective scanning techniques to obtain important aircraft data.

Conditions/Instructional Methods and Media: Part-task CBI training will be given involving various traffic scenarios which will gradually increase in complexity. Students will be presented with a series of scenarios and told to scan for a particular aircraft data element (e.g., altitude). The aircraft data element(s) being trained (e.g., altitude) will be highlighted on the data blocks and/or FPS. These highlights will be progressively faded-out over the practice trials.

At various points, the scenario will be stopped and all displays blanked out. At each point, students will be asked questions which require recall of the aircraft data element for the key aircraft involved in the scenario. Scenarios will gradually increase in complexity and number of aircraft. Finally, the student will be given exercises in which he/she will be required to recall relative altitude, location, and route type for each key aircraft.

Enabling Objectives

Scan radar blocks and/or flight strips for Altitude.

Scan radar blocks and/or flight strips for Location.

Scan radar blocks and/or flight strips for Route Type/Route.

Scan radar blocks and/or flight strips for Time at Next Fix.

Scan radar blocks and/or flight strips for Speed.

Scan radar blocks and/or flight strips for Altitude, Location, and Speed.

Standards

Identify and recall altitudes of key aircraft in sector.

Identify and recall locations of key aircraft in sector.

Identify and recall route types of key aircraft in sector.

Identify and recall time at next fix of key aircraft in sector.

Identify and recall speeds of key aircraft in sector.

Identify relative altitude, location, and route type for key aircraft in sector.

RATIONALE: Aircraft data are fundamental to sector knowledge and planning, with individual aircraft data being used to group aircraft into sector events. Thus, students must first develop effective methods for acquiring each bit of aircraft data before they can effectively identify sector events or develop sector plans. Once students have developed effective scanning patterns for acquiring each type of aircraft data, they can then develop a more comprehensive scanning pattern to obtain multiple aircraft data (e.g., altitude, location, route).

OBJECTIVE 3: Use aircraft altitude to identify potential separation violations or sequencing problems.

Conditions/Instructional Methods and Media: Students will first be given a brief classroom lecture on how to use aircraft altitude to identify potential separation violations or sequencing problems. Students will then be given various scenarios, with the data blocks or FPS including only altitude information. At various points during each scenario, the scenario will be stopped and all displays blanked out. At each point, students must describe current and future potential separation violations or sequencing problems. Throughout the practice trials, students will be required to project problems for progressively longer time ranges (e.g., 2 min. in the future, 3 min., 5 min., etc.). Feedback will be provided by comparing

the student's descriptions to expert descriptions, or with simulations or video demonstrations showing the violations and sequencing problems.

Standards

Describe all ongoing separation violations or sequencing problems.

Describe all future potential separation violations or sequencing problems, during the next 2 min., 3 min., 5 min., etc.

RATIONALE: Altitude is often the most critical aspect of aircraft data, particularly for identifying short-term separation violations or sequencing problems. ("When in doubt, altitude will bail you out.") Because of its importance, training should be provided on using altitude alone to ensure aircraft separation. This precedes Objective 4 as an advance organizer for introducing students to other aspects of aircraft data. (Since altitude is at the top of the aircraft data hierarchy in the mental model.

OBJECTIVE 4: Prioritize aircraft data in order of importance, according to varying traffic conditions.

Conditions/Instructional Methods and Media: Students will first be given a brief classroom lecture or video demonstration illustrating the usefulness and importance of various aircraft data as a function of various event types and traffic situations. Students will then be presented with a series of scenarios which vary according to the relative importance of various aircraft data. For example:

1. Scenarios requiring reliance on altitude (location, route) data for maintaining effective separation minima (note: this would likely involve a bottleneck situation requiring immediate short-term planning).

2. Scenarios requiring estimating time at next fix (such as a scenario involving long-range future potential conflictions).

3. Scenarios requiring prioritization of multiple events.

4. Scenarios requiring long-range planning involving the

use of speed control (such as sequencing a number of planes for arrival).

5. Scenarios requiring sequencing of proposals (e.g., organization of FPS in the bay).

Each series of scenarios also should present situations in the following sequence:

1. Prototypical examples. (e.g., where altitude, route are clearly the most relevant aircraft data).
2. Less clear-cut examples.
3. Borderline cases (e.g., where altitude, route may or may not be the most relevant aircraft data).
3. Non-examples (e.g., where altitude, route are not the most relevant aircraft data for answering the question).

Additionally, aspects of the situations which are common to determining the importance of certain aircraft data (e.g., altitude, route) should be emphasized by keeping these attributes constant across situations, while attributes not relevant to use of certain aircraft data should be varied across situations.

The scenarios will be frozen at various intervals and students will be asked questions about the sector situation (e.g., list potential long-term conflictions, list how you would prioritize FPS in the bay, etc.). Students will also be asked to specify which aircraft data would be most important in answering the question, and explain why. Feedback will be provided through comparisons with expert descriptions or video demonstrations/simulations describing: (1) the relative usefulness of various aircraft data, and (2) and the situational attributes relevant to making the determination.

Finally, students will be presented with the same series of scenarios, each missing the important aircraft data. (For example, a scenario requiring short-term separation with the altitude data missing.) The scenarios will be frozen at various intervals and students will be asked questions about the sector situation (e.g., list potential long-term conflictions, list how you would prioritize FPS in the bay, etc.). This will illustrate the importance of the relevant aircraft data, by demonstrating to students the difficulty in making the required determinations without it.

Standards

Select the most important aircraft data elements for each type of

event or situation. For example:

Use altitudes to diagnose and avoid critical events involving potential conflictions.

Use time at next fix for long-range diagnosis of critical events such as future potential conflictions.

Use time at next fix when presented with multiple events needing prioritization.

Use speed for long-range planning.

Use time at next fix to organize flight progress strips in the bay.

RATIONALE: After learning how to acquire and organize aircraft data, students should learn how that data varies in importance according to the situation. Students should be allowed to experiment with various situations in order to see first-hand how aircraft data is of varying use to them.

OBJECTIVE 5: Use aircraft data to group aircraft into sector events. Progressively include more aircraft in event groupings.

Conditions/Instructional Methods and Media: Students will first be given a brief lecture on using aircraft data to group aircraft into event types. Students will then be given part-task CBI training involving a series of scenarios, which will gradually increase in complexity. Each series would include a number of situations of a particular event type. For example:

1. A number of aircraft about to enter the sector.
2. A number of potential conflictions.
3. A number of aircraft requiring weather re-routing.

For each scenario, students will work in pairs to group aircraft into events by indicating which aircraft in the sector should be grouped together for purposes of handling sector events. (For example, the student might enter the call numbers of 4 aircraft, and label the grouping "aircraft entering sector.") Students will be prompted about additional aircraft

that could have been included in each grouping.

The system will then generate a series of part-task exercises by presenting each event separately that the students had identified. The computer will blank-out the rest of the aircraft on the screen and the student will be required to control the aircraft identified by the student as part of the event for the next 10-15 minutes. Then, the computer will provide feedback by generating exercises based on alternative event groupings, which the student also must control (e.g., "Now try it with this grouping _____"). Students will discuss the key differences (strengths, weaknesses, constraints) between the various grouping alternatives. Feedback will then be provided by comparing student groupings with expert groupings and aircraft data listings.

Standards

Identify sector events, and the relevant aircraft data used to determine which aircraft are included in each event. For example:

Identify aircraft about to enter the sector and their relative traffic type and speed.

Identify long-term potential conflictions and the relative time at next fix of each aircraft involved.

Identify aircraft involved in flow-control sequences and their relative locations and routes.

Identify arrivals and their relative altitudes and speeds.

Identify departures and their relative altitudes and speeds.

Identify proposals and their route and speed.

Identify aircraft requiring weather rerouting, and their routes.

Identify aircraft that require monitoring ("wait and see"), and recall their relative altitude, location, and route.

RATIONALE: Once students learn how to use individual aircraft data, they should learn how that data is used to group aircraft into sector events. Grouping aircraft into sector events is a key (if not the most essential) skill in ATC. Training in event recognition also forms the foundation for training in task recognition, because recognizing events is in many cases nearly the same as recognizing tasks. Training on recognizing what

configuration of aircraft constitutes an event of a particular type facilitates task trigger recognition, which is trained in Block 3.

OBJECTIVE 6: Organize aircraft groupings into sector events according to aircraft progress through the airspace.

Conditions/Instructional Methods and Media: Students will first be given a brief lecture on sector event classification. Students will then be given scenarios, which will gradually increase in complexity. Each series of scenarios should present situations in the following sequence:

1. Prototypical examples. (e.g., where event groupings, and which aircraft should be included in them, are clear-cut).
2. Less clear-cut examples.
3. Borderline cases (e.g., presenting a number of viable alternatives for aircraft grouping).

At the start of each scenario, students must identify and name the sector events. Feedback will be provided through comparisons with expert event classifications. Students will then work the s scenario, which will be stopped at each point immediately following the transition to a new sector event type (e.g., an on-going event becoming an event nearing completion). Students must then identify and name the sector events. Feedback will be provided through simulations or video demonstrations illustrating the various sector events and their development at various points in time throughout the scenario.

Standards

Identify aircraft entering the sector (such as aircraft entering the sector, proposals), and all key aircraft involved in the event.

Identify potential conflictions (such as ties, overtakes, conflictions), and all key aircraft involved in the event.

Identify on-going sector events (such as arrivals, departures, flow control sequences, weather reroutes, proposals, and "wait and see" aircraft), and all key aircraft involved in the event.

Identify events nearing completion, and all key aircraft involved

in the event.

RATIONALE: Once students have learned how to use aircraft data to group aircraft into events and have had some practice doing so, they need to explicitly organize the events into a pattern that is useful for understanding the overall sector situation.

OBJECTIVE 7: Correlate sector events with sector airspace characteristics.

Conditions/Instructional Methods and Media: Students will first be given a brief lecture on the relationship between sector events and sector airspace characteristics. Students will then be given scenarios which will gradually increase in complexity. At various points in the scenario, the scenario will be stopped and all displays blanked out. At each point, must correlate sector events with the related airspace characteristic. Students must identify each sector event, identify the related airspace characteristic, and describe how that characteristic may affect the event. Students will be presented with a three-dimensional representation of the sector airspace, and asked to plot (using a lightpen) sector events in relation to the airspace structure. Feedback will be provided by expert descriptions and a graphic model showing the correct correlations.

Standards

Correlate en-route structure with aircraft route types.

Correlate published arrivals, departures, and approaches with aircraft arrivals, departures, and proposals.

Correlate vertical and lateral airspace limits with aircraft entering sector, aircraft exiting sector, arrivals, and departures.

Correlate special use airspace with each sector event.

Correlate topography with each sector event.

Correlate sector traps or hot spots with each sector event.

RATIONALE: Once students have mastered sector event identification and classification, students should learn how

sector events relate to the sector airspace. Thus, students will be learning the relationship between the sector events and sector airspace aspects of the mental model (see Redding et al., 1991. Cognitive task analysis of prioritization in air traffic control: Model extension and validation, p. 10). This exercise also reinforces previous objectives by initially requiring students to identify sector events.

Objective 8: Identify important interrelationships among sector events.

Conditions/Instructional Methods and Media: Students will be presented with scenarios. Each series of scenarios should present situations in the following sequence:

1. Prototypical examples. (e.g., where the event interactions are clear-cut).
2. Less clear-cut examples.
3. Borderline cases (e.g., presenting a number of viable possibilities for sector event interactions).

Additionally, aspects of the situations which are common in determining sector event interactions should be emphasized by keeping these attributes constant across situations, while attributes not relevant to making the determination should be varied across situations.

At the start of each scenario, students will be asked to identify the sector events and to specify any events which might be considered "abnormal". Feedback will be provided through comparisons with expert sector event groupings. Then, the scenario will begin to run, but will be stopped at various points. At each point, students will be asked to describe the present and/or future effects of various sector event interactions. Student will predict interactive effects of sector event pairings (e.g., aircraft entering sector and departures), by describing what those effects will be. Throughout the practice trials, students will be required to project sector event interactions for progressively longer time ranges (e.g., 2 min. into the future, 5 min., 7 min., etc.). Feedback will be provided by a simulation or video demonstration illustrating and describing the interactive effects (for each event pairing, followed by a comprehensive simulation of the entire scenario).

Standard

Describe current sector event interactions.

Describe future sector event interactions.

Describe any abnormal or unusual sector events.

RATIONALE: Once students have mastered recognition of each sector event separately, students should develop a rule system for recognizing how events will interact in real-time. Recognition of abnormal events is introduced at this time because such events frequently have significant effects upon other events. This lesson also reinforces previous objectives by initially requiring students to identify sector events.

OBJECTIVE 9: Re-orient to sector traffic events following a break period.

Conditions/Instructional Methods and Media: Students will be given a brief lecture on effective techniques for orienting to a sector (e.g., what questions to ask, how to scan, how to correlate FPS data with radar data, etc.). After working one of the above simulations, the student will be given a break (i.e., leaving the radar console). (Scenarios should be constructed so that something unusual or unexpected has occurred in the sector traffic during the time the student is on break.) After returning from the break, the student will be shown the scenario at a future point in time. This future time frame will become progressively longer throughout the practice trials (2 min. in the future, 5 min., 10 min., etc.). The student will be given a brief time period to re-orient to the sector, with this time period becoming progressively shorter throughout practice trials. The student will then be asked questions about sector traffic events. Feedback will be provided by comparing student answers with expert descriptions, pointing out why the student failed to identify certain event.

Standards

Identify all ongoing sector events.

Identify all key future sector events in the short-term.

Identify any abnormal or unusual sector events.

RATIONALE: Once students have mastered dealing with sector

events, students should be taught how to orient to the overall sector situation by identifying all the sector events.

OBJECTIVE 10: Identify current weather factors and determine how weather conditions affect sector traffic.

Conditions/Instructional Methods and Media: Students will first be given a brief lecture on how each weather factor can affect sector traffic patterns. Students will be given scenarios which will gradually increase in complexity.

Each series of scenarios should present situations in the following sequence:

1. Prototypical examples. (e.g., where thunderstorms, turbulence clearly have an affect).
2. Less clear-cut examples.
3. Borderline cases (e.g., where thunderstorms, turbulence may arguably have an affect).

Additionally, aspects of the situations common to determining when a certain weather pattern may have an affect upon sector traffic should be emphasized by keeping those attributes constant across situations, while attributes not relevant to determining weather effects should be varied across situations.

Students will be presented with a series of part-task exercises. First, students will be given scenarios involving thunderstorms and turbulence in the sector. Next, students will be given scenarios involving weather factors affecting lift: icing, upper winds, and temperature. These exercises will require the student to describe all weather conditions in the sector, and how they will affect sector traffic.

Finally, students will be presented with "case-study" exercises involving scenarios with unusual sector traffic patterns due to whether. Students must diagnose the weather problem and location.

Feedback will be provided after each exercise through comparisons of student description(s) with expert descriptions and/or through simulations or video demonstrations illustrating the weather effects.

Standards

Identify thunderstorms and their direction of movement. Identify turbulence and its location and severity. Describe impact upon sector traffic.

Identify icing, specifying location, altitude stratum, and type. Identify upper winds, specifying location, speed, and direction. Describe impact upon sector traffic.

Identify temperature patterns. Describe impact upon sector traffic.

("**Impact**" is defined as the relative number of sector events affected:
High Impact - Affects handling of almost all events.
Moderate Impact - Affects some events.
Low Impact - Affects only one or two events.)

RATIONALE: Once students have developed a mental model for individual aircraft and sector events, they must develop a model for sector conditions and determine how such conditions will affect the sector traffic. Learning about weather conditions precedes learning about overall sector conditions, as weather often will have an impact upon the overall conditions. Thunderstorms and turbulence are taught together because these are severe weather conditions which may necessitate pilot weather deviations or significant changes in sector planning. Icing, upper winds, and temperature are taught together because these are all less-severe weather conditions which can affect aircraft lift and/or speed.

OBJECTIVE 11: Identify overall sector and area conditions and determine how these conditions affect sector traffic.

Conditions/Instructional Methods and Media: Students will first be given a brief lecture on how each key condition can affect sector traffic patterns. Students will be given scenarios which will gradually increase in complexity.

The scenarios should present situations in the following sequence:

1. Prototypical examples. (e.g., where unusual sector conditions clearly have an affect).

2. Less clear-cut examples.
3. Borderline cases (e.g., where unusual sector conditions may arguably have an affect).

Additionally, aspects of the situation common in determining whether certain conditions may have an affect upon sector traffic should be emphasized by keeping those attributes constant across situations, while attributes not relevant to determining the effects of conditions should be varied across situations.

Students will be presented with a series of part-task exercises. First, students will be given scenarios involving unusual conditions in the sector. Next, students will be given scenarios involving not only unusual conditions in the sector, but also in the area (i.e., including adjacent sectors). Then, exercises will require the student to describe conditions in the sector, conditions in the area, and overall traffic volume/complexity.

Finally, students will be presented with "case-study" exercises involving scenarios with unusual sector traffic patterns due to special sector/area conditions. Students must diagnose the weather problem and location.

Feedback will be provided after each exercise through comparisons of student description(s) with expert descriptions and/or through simulations demonstrating the effects.

Standards

Identify special conditions in the sector (such as severe weather avoidance procedures, change in number of miles in trail, etc.). Describe the affects upon sector traffic.

Identify special conditions in the area as a whole (such as flow control directives, equipment outages, severe weather avoidance procedures, etc.). Describe the affects upon sector traffic.

Determine traffic volume/complexity. Describe the affects upon sector traffic.

RATIONALE: Once students have developed a mental model for individual aircraft and sector events, they must develop a model of overall sector conditions and how such conditions will affect the sector traffic. (Special conditions may result from weather conditions.)

OBJECTIVE 12: Construct own comprehensive mental model of en-route air traffic control.

Conditions/Instructional Methods and Media: After a classroom discussion of the mental model concept (what is a mental model, what forms can they take, how are they useful?) a video will be shown describing generic mental models of en-route ATC, describing how they are structured and used. Then, each student will work at constructing his/her own model by diagraming it. Students will be instructed that their model should account for: sector events, individual aircraft, weather, and sector conditions. Then, students will break up into small groups and discuss each other's models. Students should explain how his/her model helps serve the functions listed below, identify key differences between each other's models (in terms of their constraints, structure, and underlying causal relationships), and compare the relative strengths and weaknesses of their models. After the small group discussions, each student will discuss his/her mental model with an expert controller who will provide individualized feedback and suggestions.

Standards

Develop a model which:

Organizes the key spatial characteristics of the airspace.

Organizes individual aircraft data according to relative importance.

Groups aircraft into sector events.

Relates sector events to airspace characteristics.

Interrelates sector events.

Provides a template for orienting to the sector and sector traffic.

Organizes weather patterns or factors.

Determines sector conditions and workload.

RATIONALE: Once students have been instructed on each component of the mental model (as represented by the previous objectives), they should use that knowledge to construct their own comprehensive mental model for ATC. Because each student should construct a model which is most useful to him/her, student models

will differ. However, because experts models share common key features, student models should include these key features. Student models must also be useful in supporting key aspects of problem-solving and decision-making in ATC. (The expert organizers will also be helpful to students in constructing their own models, and will help students to generalize from the previously-learned objectives. Each organizer relates to an objective, or block of related objectives, thus reinforcing previous objectives.)

BLOCK 2. PLANNING.

Lesson Goal: Develop short- and long-term planning skills.

Time: ---- Days.

Lesson Plan

OBJECTIVE 1: Identify the affects of various aircraft characteristics upon aircraft performance capabilities under varying traffic conditions.

Conditions/Instructional Methods and Media: Students will first be given a brief lecture and/or workbook exercise on how various aircraft characteristics can affect the pilot's ability to implement various air traffic control directives. Students will then be given a gaming exercise in which they can vary the aircraft performance characteristics (e.g., aircraft speed, rate of climb, or maneuverability capabilities) and sector conditions (e.g., thunderstorms, low temperatures, icing). Students will then select a control option from a menu, and the system will show the aircraft response (e.g., speed, rate of descent, lift, communication, etc.). Then, students will be given traffic scenarios in which the performance parameters of individual aircraft are systematically varied. Scenarios will gradually increase in complexity. Students will be asked to describe how the parameter change affects the aircraft and to select (from a menu) the control actions which would be ineffective given the traffic situation, sector conditions, and the performance parameters. Feedback will be provided after each exercise through video demonstrations or simulations explaining how the parameter change affected aircraft performance and comparing effective with ineffective control actions.

NOTE: This objective could alternatively be taught under Block 4 (strategy selection).

Standards

Identify relationships between aircraft characteristics and aircraft performance capabilities.

Identify ineffective control actions for varying aircraft performance characteristics (such as asking a Concord pilot to

stop a descent).

RATIONALE: Fundamental to effective planning is an understanding of how aircraft performance characteristics can affect a pilot's ability to comply with controller instructions. By allowing students to actually see the affects of various aircraft characteristics under varying conditions, students can develop their own rule system for understanding the relationship between aircraft characteristics and planning. This approach also facilitates long-term retention.

OBJECTIVE 2: Determine criticality and time-window of future sector events.

Conditions/Instructional Methods and Media: Students will first be given a brief lecture on methods for estimating the time-window for each type of sector event, and how various event types differ in criticality as a function of varying traffic conditions. Students will then be given scenarios along with descriptions of the future sector events. Students must rate the criticality of the future event and estimate how far into the future it will occur. Throughout the practice exercises, students will be asked to project future sector events for progressively longer time frames (e.g., 3 min. in the future, 5 min., 7 min., etc.). Scenarios will gradually increase in complexity. Feedback will be provided through comparisons with expert ratings and estimations, with the accompanying rationales. Students will then watch the actual scenario develop. The system will indicate (through auditory and visual prompts) the point in the scenario at which the student had predicted the event would begin to occur as well as the point at which it actually does begin, in order to show the discrepancy between the student's prediction and the real-time events.

Standards

Correctly rate the criticality of each future sector event.

Correctly estimate the time window of each future sector event.

RATIONALE: In order to plan for sector events, students must first be able to judge when those events are likely to occur and their relative importance.

OBJECTIVE 3: Determine criticality and time-window of future weather patterns.

Conditions/Instructional Methods and Media: Students will first be given a brief lecture on methods for estimating the time-window for each type of weather pattern, and how various weather events differ in criticality as a function of varying traffic conditions. Students will then be given a scenario along with descriptions of the future weather events. Students must rate the criticality of the future event and estimate how far into the future it will occur. Throughout the practice exercises, students will be asked to project future sector events for progressively longer time frames (e.g., 3 min. in the future, 5 min., 7 min., etc.). Scenarios will gradually increase in complexity. Feedback will be provided through comparisons with expert ratings and estimations, with the accompanying rationales. Students will then watch the actual scenario develop. The system will indicate (through auditory and visual prompts) the point in the scenario at which the student had predicted the event would begin to occur and the point at which it actually does begin, in order to show the discrepancy between the student's prediction and the real-time events.

Standards

Correctly rate the criticality of each future weather event.

Correctly estimate the time window of each future weather event.

RATIONALE: In order to plan for sector events, students must first be able to judge when those events are likely to occur and their relative importance. Weather follows sector events, consistent with the organization of the mental model training sequence (Block 1) wherein conditions are taught after sector events.

OBJECTIVE 4: Develop a procedural plan to achieve short-term aircraft separation.

Conditions/Instructional Methods and Media: Students will first be given a brief lecture on procedural techniques for achieving short-term aircraft separation. Students then will be presented with scenarios requiring immediate aircraft separation in order to avoid a confliction. Scenarios will gradually increase in complexity and time-criticality.

Each series of scenarios should present situations in the following sequence:

1. Prototypical examples. (e.g., where the plan for achieving short-term separation is apparent and clear-cut).
2. Less clear-cut examples.
3. Borderline cases (e.g., presenting a number of viable alternatives for achieving separation).

Additionally, aspects of the situations commonly requiring use of particular procedures or plans should be emphasized by keeping these attributes constant across situations, while attributes not relevant to key aspects of planning should be varied across situations.

Students must formulate a control plan for each scenario, and diagram their plan (i.e., construct a decision tree), showing alternatives for each decision point. Students will then split-up into pairs and systematically compare their diagrams, identifying important differences between the two and developing one optimal plan. Students then will be presented with an expert procedural plan. Students will then control the scenario twice: once using their plan, the other time using the expert plan. Students will then compare the two plans, and then revise their plan to reflect the optimal procedures.

Feedback will again be provided through comparisons with an expert plan, particularly concerning aspects involving the use of aircraft data (altitude, time at next fix, etc.) and the key cognitive operations involved. The expert plan should show the primary decision options at each point, identifying which ones are optimal. Students will be asked to identify key differences between their plans and the expert plan, and the strengths and weaknesses of each option. Students should identify those portions of the expert plans that are superior to their own (and/or vice-versa). Importantly, the instructor should explicitly point out to students the underlying principles which make the expert plan superior, for each point in the sequence.

NOTE: This exercise is not designed to teach specific control strategies (Block 3), although some overlap may be unavoidable (and not undesirable). Rather, the goal is to teach decisionmaking and planning procedures related to short-term separation. Some overlap may be unavoidable, however (and is not undesirable).

Standards

Develop effective plans for short-term separation.

RATIONALE: Once students can predict the time-frame of events, they should be taught basic planning techniques, the most fundamental of which is planning to ensure short-term separation. Paired problem-solving exercises allow students to work in an environment where they are not constrained by ongoing real-time events.

OBJECTIVE 5: Develop primary and back-up short-term plans for each aircraft, using key aircraft data.

Conditions/Instructional Methods and Media: Students will be presented with scenarios of sufficient complexity and/or time constraints, necessitating short-term planning. The only aircraft data provided will be altitude, location, and route type.

Each series of scenarios should present situations in the following sequence:

1. Prototypical examples requiring short-term planning. (e.g., where the effective short-term plans are apparent and clear-cut).
2. Less clear-cut examples.
3. Borderline cases (e.g., presenting a number of short-term plan alternatives).

Additionally, aspects of the situations requiring use of particular procedures or plans should be emphasized by keeping these attributes constant across situations, while attributes not relevant to key aspects of planning should be varied across situations.

Students will be asked to develop at least two short-term plans (i.e., ones which can be implemented within 1-5 minutes), for several key aircraft. Students will then split-up into pairs and systematically compare their diagrams, identifying important differences between them and developing optimal plans. Students then will be presented with expert procedural plans for the aircraft. Students will then control the scenario twice: once using their plan(s), the other time using the expert plan(s). Students will then compare the plans, and then revise their plan(s) to reflect the optimal procedures.

Feedback will then be provided through comparisons with expert plans, particularly concerning aspects of the plans involving the use of aircraft data and the key cognitive operations involved. The expert plan should show the primary

decision options at each point, identifying which ones are optimal. Students will be asked to identify key differences between their plan and the expert plan, and the strengths and weaknesses of each option. Students should identify those portions of the expert plans that are superior to their own (and/or vice-versa). Importantly, the instructor should explicitly point out to students the underlying principle which makes the expert plan superior, for each point in the sequence.

Standards

Describe primary short-term plan for each aircraft.

Describe back-up short-term plan(s) for each aircraft.

RATIONALE: Once students have mastered the fundamental aspects of short-term planning, they should be taught to develop primary and backup plans to handle various sector events involving key aircraft. Short term planning should be taught before long term planning, as long term planning requires greater expertise. Paired problem-solving exercises allow students to work in an environment where they are not constrained by ongoing real-time events. This allows students to compare and modify their plans and is thus a good environment in which to develop short-term planning skills. This lesson also reinforces objectives 3 and 4 in Block 1, by again emphasizing the importance of aircraft altitude, location, and route in short-term planning.

OBJECTIVE 6: Develop primary and back-up long-term plans for each event separately, followed by plans for multiple events.

Conditions/Instructional Methods and Media: Part-task training will be given involving presentation of a series of scenarios, each series involving a particular event type. Students will then be given complete scenarios of varying complexity and conditions. Scenarios will gradually increase in complexity.

Each series of scenarios should present situations in the following sequence:

1. Prototypical examples. (e.g., where the event is apparent and clear-cut).

2. Less clear-cut examples of the event type.
3. Borderline cases (e.g., where the event is not readily discernible).

Additionally, aspects of the situations common to the event type should be emphasized by keeping these attributes constant across situations, while attributes not relevant for identification of the event should be varied across situations.

Students will be presented with limited scenarios which present real-time events and data only in relation to a particular sector event type (e.g., aircraft entering the sector). (The other aircraft on the screen will remain static throughout the problem, with the data for them also remaining constant.) Students must identify the event and then develop a long-term plan to handle the particular event. Throughout the practice exercises, students will be required to develop a plan for progressively longer time frames (e.g., next 5 min. into the future, next 10 min., 15 min., 20 min, etc.) and control the sector for the time frame using the plans they developed. Feedback will be provided by presenting simulations or video demonstrations of alternative expert plans and resulting outcomes (showing how the events would have evolved using the expert plans).

Standards

Generate an effective long-term plan.

Generate an effective back-up long-term plan.

RATIONALE: Once students have mastered short-term planning, long term planning skills should be trained. This lesson also reinforces previous objectives by initially requiring students to identify sector events under varying conditions of clarity.

OBJECTIVE 7: Translate long-term plans into detailed plans of specific control actions involving individual aircraft (i.e., short-term plans).

Conditions/Instructional Methods and Media: After the previous lesson (Objective 6), students will be asked to decompose their long-term plan one or two of the scenarios, into a series of short term plans to handle each future event, listing the:

1. Applicable component of the long-term plan (i.e., describe how each short-term plan wad derived from the long-term plan).

2. Event it applies to.

3. Anticipated time-frame of the future event.

4. Procedural steps involved in the short-term plan.

Students will then split-up into pairs and systematically compare diagrams identifying the differences between their plans and revise them to develop an optimal plan. The scenario will then be fast-forwarded to points which require immediate implementation of a short-term plan (such as to avoid conflictions, etc.). The must implement the appropriate short-term plan from those they developed. Feedback will be provided by comparing student diagrams with expert diagrams and through simulations or video demonstrations illustrating the implementation of expert short-term plans.

Standards

Develop an effective long-term plan.

Decompose long-term plan into effective short-term plans for dealing with each aircraft.

RATIONALE: Once students have mastered both short-term and long-term planning, they should be taught about the relationship between the two: How a long-term plan gets implemented through a series of short-term plans. Paired problem-solving exercises allow students to work in an environment where they are not constrained by ongoing real-time events. This allows students to compare and modify their plans and is thus a good environment in which to practice short-term planning skills. This lesson also reinforces objectives 3 and 4 in Block 1, by again emphasizing the importance of aircraft altitude, location, and route in short-term planning. The lesson also reinforces other previous objectives by initially requiring students to identify events and event time frames.

OBJECTIVE 8: Determine when back-up plan(s) should be used.

Conditions/Instructional Methods and Media: Students will

be presented with scenarios, which will be constructed in such a way as to suggest a clearly identifiable optimal solution plan. which would be ineffective if a key sector condition or parameter were changed (e.g., thunderstorm in a particular area of the sector, aircraft performance capabilities altered, new flow control directive, etc.). Students will be asked to develop both a primary long-term plan and primary short-term plan for each scenario. Students will then be required to develop back-up plans and identify the conditions under which they should be implemented. Feedback will be provided through comparisons with expert descriptions.

Students will then work in pairs, playing "what if" with each other: one student develops a "what if" scenario which would change the current situation, and presents it to the other student. The other student must then determine how the change in parameter would require changing the primary plan or reverting to the backup plan.

Standards

Identify the factor(s) necessitating a plan change. Identify the change(s) that should be made in the primary plan (i.e., develop a backup plan).

RATIONALE: Once students have mastered the range of planning skills, they should be taught how to evaluate the effectiveness of their plans: Under what conditions will the primary plan be ineffective? By experimenting with scenarios which are constructed in a manner such that every key parameter change requires an accompanying change in plans, students can develop a rule system for identifying predictable elements which will necessitate plan changes.

OBJECTIVE 9: Determine how sector-specific airspace features affect planning.

Conditions/Instructional Methods and Media: Students will first be given a brief lecture on how differences in airspace features between sectors can affect planning. Students will then be presented with airspace sectors of varying characteristics. First, airspaces should vary only along one characteristic (e.g., en-route structures), with the variation from the first example increasing throughout the series. Then, students should be presented with airspaces varying along two or three characteristics, with the variation from the first example

increasing throughout the series. Finally, students should be presented with airspaces varying along multiple characteristics, with the variation from the first example increasing throughout the series.

Students will be given workbook exercises requiring them to describe how the characteristics of each sector would affect their planning, and to compare and contrast the sector differences with accompanying differences in overall planning approaches. Importantly, students should identify how the sector airspace characteristic constrains their planning options. Students will also be presented with a control plan for each series of scenarios, and they must identify (for each scenario) those aspects of the plan which would not be effective due to the unique features of the sector airspace. Feedback will be provided through simulations or video demonstrations illustrating the effectiveness of the plans across the varying airspaces, and through classroom discussion.

Standards

Determine how lateral and vertical limits of sector geography (sector boundaries, airport locations, NAVAID locations) affect planning. Identify differences in geography between the sectors.

Determine how en-route structures affect planning. Identify differences in en-route structures between the sectors.

Determine how published arrivals, departures, and approach paths affect planning. Identify important differences between the sectors.

Determine how special use airspace affects planning. Identify differences in special use airspace between the sectors.

Determine how topography affects planning. Identify important topographical differences between the sectors.

Determine how sector traps or hot spots affects planning. Identify differences in traps or hot spots between the sectors. (**NOTE:** This may require experience in working the various sectors.)

RATIONALE: Fundamental to effective planning is understanding how the sector airspace features affect planning options. Students will discover this by comparing features of different airspaces, and relating differences in features to planning techniques. This objective comes last in this block, because it requires students to transfer the planning skills they have

already acquired to different types of sector airspace.

BLOCK 3. CONTROLLER TASKS.

Lesson Goal: Recognize when a task should be performed and the key operations associated with the task, and prioritize among competing tasks.

Time: ----- Days.

Lesson Plan

OBJECTIVE 1: Recognize the task trigger for each task, under varying conditions of clarity.

Conditions/Instructional Methods and Media: Students will be given a brief lecture on the controller tasks, with a video demonstration showing the range of task triggers for each task. Students will then be presented with a series of part-task rapid-recognition exercises on a CBI system equipped with a time clock. Students will first be given a series of demonstration simulations in which a limited scenario is presented, which includes the trigger for one particular task. When the trigger is presented, a prompt will be flashed on the screen indicating the trigger and highlighting the portion(s) of the scenario where it occurs. Following the demonstration series for each task, scenarios will be presented which require the student to identify task triggers as fast as possible after they are presented (by pressing a button). After training on each individual task, the student will be given exercises which present various tasks alternatively.

Each series of scenarios should present task triggers in the following sequence:

1. Prototypical examples. (e.g., where the trigger is apparent and clear-cut).
2. Less clear-cut examples.
3. Borderline cases (e.g., where the trigger is not readily discernible).

Additionally, aspects of the situations characteristic of the trigger should be emphasized by keeping these attributes constant across situations, while attributes not relevant for identification of the trigger should be varied across situations.

Feedback given will either be: "Too Soon" (if the student responded when the trigger not yet present), "Good, but Respond _____ Seconds Sooner" (if student did not immediately recognize the trigger), or "Right" (if student recognized the trigger within 3-5 seconds). If the student responded too early or too late, the computer will replay the scenario, showing (through auditory and visual prompts) when the trigger first appeared. The following summarizes the lesson design for this objective:

1. Demonstration simulations for Task 1:
   - Trigger 1.
   - Trigger 2.
   - Trigger 3., etc.

2. Practice exercises for Task 1 (random presentation of triggers), with simulation replays. For example:
   - Trigger 1.
     - Simulation replay of Trigger 1.
   - Trigger 3.
     - Simulation replay of Trigger 3.
   - Trigger 3
     - Simulation replay of Trigger 3.
   - Trigger 2, etc.
     - Simulation replay of Trigger 2.

3. Repeat sequences 1 and 2 above for <u>each task</u>.

4. Practices exercises for all tasks (random presentation of tasks and an associated trigger), with simulation replays. For example:
   - Task 1, Trigger 3
     - Simulation replay of Task 1, Trigger 3.
   - Task 5, Trigger 2.
     - Simulation replay of Task 5, Trigger 2.
   - Task 4, Trigger 1.
     - Simulation replay of Task 4, Trigger 1.

NOTE: This exercise is not intended to train <u>when a task should</u> be performed in an actual environment, only the <u>recognition</u> of tasks. The amount of part-task training devoted to each task will depend upon the task's importance, the number of different triggers each task has, and the difficulty in recognizing triggers for the task.

<u>Standards:</u>
<u>Recognize task triggers for the task:</u>

Resolve Aircraft Conflict.

Reroute Aircraft.

Manage Arrivals.

Manage Departures.

Manage Overflights.

Receive Handoff.

Receive Pointout.

Issue Advisory.

Issue Safety Alert.

NOTE: Tasks not generally amenable to trigger recognition training are not included.

RATIONALE: In order to train towards rapid, effortless recognition of task triggers, part-task training should be provided on each task over a compressed time period. Once students have mastered each task separately, they should be trained in an environment which randomly presents different tasks. By presenting triggers at various degrees of clarity, students can see the various conditions under which a task might be triggered. Training around task triggers, and thus problem types, also promotes mental model development. The two primary cognitive tasks Maintain Situation Awareness and Update and Revise Sector Control Plan are not included because they should always be carried-out whenever no other tasks are being performed (see Redding, et al., 1991. Cognitive task analysis of prioritization in air traffic control: Model extension and validation, p. 28-29). The tasks Receive Handout and Receive Pointout are not included because these are discretionary tasks with no clear triggers.

OBJECTIVE 2: Determine how aircraft data trigger controller tasks.

Conditions/Instructional Methods and Media: Students will be given various traffic scenarios. For each scenario, students will be asked to list the key/critical aircraft data and the task(s) they trigger. Feedback will be provided through comparisons with expert listings.

Then, students will be given scenarios which present various tasks as a result of changes in aircraft data. The scenarios

should present tasks in the following sequence:

1. Prototypical examples. (e.g., where changes in aircraft data clearly trigger certain tasks).
2. Less clear-cut examples.
3. Borderline cases (e.g., where the relationship between changes in aircraft data and tasks may not be readily discernible).

Additionally, aspects of the aircraft data which are common triggers of the task(s) should be emphasized by keeping these attributes constant across situations, while aspects of aircraft data not generally relevant to triggering a task should be varied across situations.

Each scenario will be frozen at various points, including those points when a situational change in aircraft data triggers a task. Whenever the scenario is frozen, students will be asked which tasks are being triggered, and what changes in aircraft data are triggering the task. Feedback will be provided through computer graphics or video demonstrations highlighting the relevant/critical aircraft data and associated task triggers for each scenario.

Standards

Identify tasks triggered (such as issue advisory, initiate/receive pointout, initiate/receive handoff, reroute aircraft, resolve aircraft conflict), and what aircraft data trigger them.

RATIONALE: Once students have mastered each of the task triggers, they should be taught how tasks are related to the mental model: What patterns of information in the mental model triggers which tasks? Aircraft data is taught before sector events, consistent with the sequencing of the mental model development exercises (Block 1). This lesson also reinforces Objective 4 (Determine relative importance of aircraft data) in Block 1, by varying across situations aircraft data are not relevant to a task.

OBJECTIVE 3: Determine how sector events trigger controller tasks.

Conditions/Instructional Methods and Media: Students will be given various traffic scenarios. For each scenario, students

will be asked to list the sector events and the task(s) they trigger. Feedback will be provided through comparisons with expert listings.

Then, students will be given scenarios which present various tasks as a result of changes in sector events. The scenarios should present tasks in the following sequence:

1. Prototypical examples. (e.g., where changes in sector events clearly trigger certain tasks).
2. Less clear-cut examples.
3. Borderline cases (e.g., where the relationship between changes in sector events and tasks may not be readily discernible).

Additionally, aspects of sector events which are common triggers of the task(s) should be emphasized by keeping these attributes constant across situations, while aspects of sector events not generally relevant to triggering a task should be varied across situations.

Each scenario will be frozen at various points, including those points when a situational change in sector events triggers a task. Whenever the scenario is frozen, students will be asked which tasks are being triggered, and what sector event changes are triggering the task. Feedback will be provided through computer graphics or video demonstrations highlighting the relevant/critical sector events and associated task triggers for each scenario.

Standards

Identify aircraft entering the sector and tasks triggered (such as receive handoff, manage departure).

Identify on-going events and tasks triggered (such as manage arrivals).

Identify potential conflictions and tasks triggered (such as issue safety alert, resolve aircraft conflict).

Identify requests and tasks triggered (such as reroute aircraft, manage departures, and receive pointout).

RATIONALE: Once students have mastered each of the task triggers, they should be taught how tasks are related to the mental model: What patterns of information in the mental model triggers which tasks? Sector events is taught before sector conditions, consistent with the sequencing of the mental model development exercises (Block 1).

OBJECTIVE 4: Determine how sector and area conditions trigger controller tasks.

Conditions/Instructional Methods and Media: Students will be given various traffic scenarios. For each scenario, students will be asked to list the sector conditions and the task(s) they trigger. Feedback will be provided through comparisons with expert listings.

Then, students will be given scenarios which present various tasks as a result of changes in sector conditions. The scenarios should present tasks in the following sequence:

1. Prototypical examples. (e.g., where changes in sector conditions clearly trigger certain tasks).
2. Less clear-cut examples.
3. Borderline cases (e.g., where the relationship between changes in sector conditions and tasks may not be readily discernible).

Additionally, aspects of sector conditions which are common triggers of the task(s) should be emphasized by keeping these attributes constant across situations, while aspects of sector conditions not generally relevant to triggering a task should be varied across situations.

Each scenario will be frozen at various points, including those points when a situational change in sector events triggers a task. Whenever the scenario is frozen, students will be asked which tasks are being triggered, and what sector condition changes are triggering the task. Feedback will be provided through computer graphics or video demonstrations highlighting the relevant/critical sector conditions and associated task triggers for each scenario.

Standards

Students will identify tasks triggered as a function of changes in sector conditions. For example:

Determine situation in the sector and area, and tasks triggered (such as reroute aircraft, issue advisory, manage departures).

Determine thunderstorms and upper winds, and tasks triggered (such as reroute aircraft, issue advisory).

RATIONALE: Once students have mastered each of the task triggers, they should be taught how tasks are related to the mental model: What patterns of information in the mental model trigger which tasks? Conditions are taught last because conditional changes trigger tasks infrequently (see Redding et al., 1991. Cognitive Task Analysis of En Route Air Traffic Control: Model Extension and Validation, p.47). This is also consistent with the sequencing of the mental model development exercises (Block 1).

OBJECTIVE 5: Determine task priorities when multiple tasks are triggered simultaneously or nearly simultaneously.

Conditions/Instructional Methods and Media: Students will be presented with scenarios which present several tasks simultaneously.

The scenarios should be presented in the following sequence:

1. Prototypical situations (e.g., where the task prioritization is apparent and clear-cut).
2. Less clear-cut situations.
3. Borderline situations (e.g., where several alternatives for task prioritization are viable).

The scenarios will also become progressively more complex and difficult (greater criticality, shorter time-windows, more simultaneous tasks, greater traffic volume, etc.).

The student must identify and prioritize the tasks, and choose one task to execute first. The student will then handle that task only, until its completion (or interruption). So that students may compare the effects of different prioritizations, the scenario will be presented again at the start point and the student must begin by handling another task (i.e., a task not chosen as first priority) until completion (or interruption). Feedback will also be given through comparisons with expert priority listings. Importantly, instructors should explicitly point-out the principles underlying the expert prioritization scheme and discuss the strengths and weaknesses of alternative prioritizations (including the mental resource costs, and how varying prioritization sequences would result in different constraints upon the development of the scenario).

Standards

Effectively prioritize tasks.

RATIONALE: Once students have mastered recognition of individual tasks and the relationship between sector information and task triggers, they should be taught prioritization skills for competing tasks. The task triggers contain an implicit rather than explicit prioritization scheme. By experimenting with different prioritization schemes under varying conditions, however, students can develop their own rule structures and heuristics for prioritization. This lesson also reinforces previous objectives by initially requiring students to identify the tasks (and thus, the task triggers).

OBJECTIVE 6. Determine procedures necessary to carry out each task, particularly those involving cognitive operations (i.e., decision-making, problem-solving, and monitoring/situation assessment).

Conditions/Instructional Methods and Media: Students will be presented with generic scenarios, each representative of a particular controller task. The student must list the main monitoring, planning, and decisionmaking actions/goals in sequential order (i.e., construct a decision tree). Students must then handle the scenario using the sequence they outlined. Students will obtain feedback by seeing the effectiveness of their procedural plan as they control the scenario. Feedback will also be given through comparisons with expert listings. Importantly, instructors should explicitly point-out the principles underlying the expert sequencing and discuss the strengths and weaknesses of alternative sequencings (including the mental resource costs, and how varying sequences would result in different constraints upon the development of the scenario).

Then, students will be given another series of part-task exercises involving a particular controller task, with the scenarios increasing in complexity throughout the series. Each scenario will be frozen at points which will require a number of cognitive procedures within the next few minutes. At each point, the student must identify the actions to be taken to carry out the task during the next ___ minutes. Feedback will be provided through comparison with expert action listings with accompanying simulations or video demonstrations.

Standards

Identify and sequence key monitoring, decisionmaking, and planning goals/actions for each controller task:

Resolve Aircraft Conflict.

Reroute Aircraft.

Manage Arrivals.

Manage Departures.

Manage Overflights.

Receive Handoff.

Receive Pointout.

Issue Advisory.

Issue Safety Alert.

Students should identify the following in each of their plans:

Incorrect sequencing in the plan.

Unnecessary subgoals in the plan.

Subgoals which should be added to the plan.

Subgoals that should be combined.

Subgoals that should be broken down into components.

RATIONALE: After students have mastered task recognition and prioritization, they should be taught about the contents of each task: What is required to fully execute each task? What are they key decision points? Rather than memorizing prepared lists of action sequences for each task, students should develop their own rule structures through exposure to tasks under varying conditions. This approach also facilitates long-term retention.

BLOCK 4. STRATEGY SELECTION

Lesson Goal: Develop a repertoire of strategies, and an understanding of strategy selection methods.

Time: ----- Days.

Lesson Plan

OBJECTIVE 1: Identify and learn to use a range of Planning strategies.

Conditions/Instructional Methods and Media: Students will be taught a range of planning strategies through classroom lecture and video demonstration. Instruction should begin with high-level strategies. Students should then be gradually introduced to the lower-level strategies, with their relationships to the higher-level strategies explicitly pointed out. Similarly, whenever a new strategy is introduced, it should be related to a previously learned strategy (through analogy, contrasts, and comparisons).

Students will then be given workbook exercises in which they must choose the correct planning strategies for specific traffic situations. The exercises should include several situations applicable to each type of strategy or set of strategies, in the following sequence:

1. Prototypical situations (e.g., where it is apparent and clear cut which strategy or set of strategies is to be used).
2. Less clear-cut situations.
3. Borderline cases (e.g., where several different types of strategies are viable).

Additionally, aspects of the situations which are common to a particular strategy or set of strategies should be emphasized by keeping these attributes constant across situations. Aspects of the situation not generally relevant to strategy selection should varied across situations.

Feedback will be given by comparing student strategy choices with expert choices, illustrating through a simulation or video demonstration the implementation of the expert choices.

Standards

Identify appropriate planning strategies for each control situation.

RATIONALE: In order to introduce students to strategies, they should first be exposed to a range of strategies with accompanying demonstrations. Planning strategies are taught before monitoring or workload reduction strategies because planning skills have just been taught in the previous blocks.

OBJECTIVE 2: Develop an efficient organizational structure for Planning strategies, by grouping strategies according to sector event type.

Conditions/Instructional Methods and Media: Students will first be given a brief lecture on the relationship between strategies and sector event types. Students will then be presented with a series of limited scenarios, with each series showing a particular type of sector event. Students must first identify the sector event and then identify strategies which could be used to handle the event (particularly those unique or especially appropriate to handling the event type).

The scenarios should include situations in the following sequence:

1. Prototypical cases (e.g., where it is apparent and clear cut which strategies should be used).
2. Less clear-cut cases.
3. Borderline cases (e.g., where it difficult to discern which strategies should be used).

Additionally, aspects of the events which are common to a particular strategy or set of strategies should be emphasized by keeping these attributes constant across situations. Aspects of the events not generally relevant to strategy selection should varied across situations.

Feedback will be given by comparing student strategy choices with expert choices, as illustrated through a simulation or video demonstration the implementation of the expert strategy choices (particularly those unique to the sector event).

Standards

Correctly correlate strategies with each type of sector event. For example:

Identify effective strategies for handling conflictions. For example:
- Determine the nature of the overtake
- Determine amount of time available to affect separation once aircraft in the sector

Identify effective strategies for handling arrivals. For example:
- Determine sequence
- Determine nature of the overtake
- Determine which aircraft to make first
- Let speed take effect
- Prioritize actions

NOTE: The above listing of examples represents categories of strategies, no the specific strategies themselves.

RATIONALE: The vast number of strategies requires some organizational structure for determining when to use which strategies. Sector events provide the ideal organizer for grouping strategies, because ATC is best accomplished with reference to sector events. This lesson also reinforces previous objectives by initially requiring students to identify sector events.

OBJECTIVE 3: Understand the relationship between time-criticality and use of Planning strategies.

Conditions/Instructional Methods and Media: Students will be presented with a series of scenarios. Each scenario will be presented three times under conditions of increasing time criticality:

1. Low criticality (ample time for planning, with no bottlenecks)
2. Medium criticality
3. High criticality (little time for planning, with bottleneck situation quickly developing).

Students will be asked to develop and implement a plan at the start of the low criticality scenario. Students will be told that they will be given the same scenario again involving the same events, but that the scenario will be speeded-up by x-number

of minutes. Students will work the scenario again. Students will obtain feedback by seeing the effectiveness of their sector plan under varying conditions of time-criticality. After each series, students will identify what aspects of their plan would need to be modified in order to deal with the increased time criticality. Feedback will be provided through simulations or video demonstrations illustrating how elimination or re-sequencing of various subgoals under time-constrained conditions improves the effectiveness of a (generic) plan.

Standards

Identify plan subgoals that must be eliminated under high time-criticality conditions (to reduce mental workload).

Identify plan subgoals that must be re-sequenced under high time-criticality conditions.

NOTE: This objective differs from later objectives aimed at teaching workload management strategies, because the lesson goal is to identify optimal subgoal sequences within plans rather than specific strategies for reducing workload. It also differs from Block 7 (workload reduction) which teaches general techniques for reducing overall controller workload.

RATIONALE: Once students have mastered planning strategies, they should be taught strategy selection methods in relation to future time-frames. One of the fundamental aspects of effective planning is being able to formulate a plan based upon the time-frame in which the controller has to accomplish various goals and tasks. There are few explicit rules concerning planning in relation to time-criticality, with controllers showing idiosyncratic approaches. Students can best develop their own rule structures and heuristics for planning in relation to time-criticality by experimenting and seeing how a plan's effectiveness will differ under varying time-constraints.

OBJECTIVE 4: Relate Planning strategies to controller tasks. For each task, identify strategies appropriate for execution of important task subgoals. Identify differences in strategy effectiveness under varying sector conditions.

Conditions/Instructional Methods and Media: Students will be asked to list the key tasks/subgoals for each task, in sequential order (i.e., construct a decision tree). Feedback will be given through comparisons with expert listings.

Instructors should explicitly point out the importance of each key subgoal. Students will then be asked to list planning strategies which could be used to implement each key subgoal and identify the optimal strategies for each subgoal. Feedback will be given through comparisons with expert listings. There will also be a class discussion concerning strategies listed by the students which were not listed by the experts, discussing strengths and weaknesses of various strategies. Students will also be shown videos demonstrating or describing the use of different strategies with each key subgoal.

Standards

Identify effective strategies for implementing each key task subgoal, for the following controller tasks:

Resolve Aircraft Conflict.

Reroute Aircraft.

Manage Arrivals.

Manage Departures.

Manage Overflights.

Receive Handoff.

Receive Pointout.

Issue Advisory.

Issue Safety Alert.

RATIONALE: Once strategies have been learned at the event level, they should be practiced at the task level so students can learn the specific conditions under which they are to be implemented. Training should demonstrate the representative range of strategies for implementing task subgoals. This lesson also reinforces previous objectives by requiring students to identify key subgoals for each task.

OBJECTIVE 5: Identify and learn to use a range of Monitoring strategies.

Conditions/Instructional Methods and Media: Students will

be taught a range of monitoring strategies through classroom lecture and video demonstration. Instruction should begin with high-level strategies. Students should then be gradually introduced to the lower-level strategies, with their relationships to the higher-level strategies explicitly pointed out. Similarly, whenever a new strategy is introduced, it should be related to a previously learned strategy (through analogy, contrasts, and comparisons).

Students will then be given workbook exercises in which they must choose the correct planning strategies for specific traffic situations. The exercises should include several situations applicable to each type of strategy or set of strategies, in the following sequence:

1. Prototypical situations (e.g., where it is apparent and clear cut which strategy or set of strategies is to be used).
2. Less clear-cut situations.
3. Borderline cases (e.g., where several different types of strategies are viable).

Additionally, aspects of the situations which are common to a particular strategy or set of strategies should be emphasized by keeping these attributes constant across situations. Aspects of the situation not generally relevant to strategy selection should varied across situations.

Feedback will be given by comparing student strategy choices with expert choices, illustrating through a simulation or video demonstration the implementation of the expert choices.

Standards

Identify appropriate monitoring strategies for each control situation.

RATIONALE: In order to introduce students to strategies, they should first be exposed to a range of strategies with accompanying demonstrations. Monitoring strategies are taught before workload reduction strategies because effective monitoring is generally a prerequisite to effective workload reduction.

OBJECTIVE 6: Develop efficient organizational structure for Monitoring strategies, by grouping strategies according to sector event type.

Conditions/Instructional Methods and Media: Students will first be given a brief lecture on the relationship between strategies and sector event types. Students will then be presented with a series of limited scenarios, with each series showing a particular type of sector event. Students must first identify the sector event and then identify strategies which could be used to handle the event (particularly those unique or especially appropriate to handling the event type).

The scenarios should include situations in the following sequence:

1. Prototypical cases (e.g., where it is apparent and clear cut which strategies should be used).
2. Less clear-cut cases.
3. Borderline cases (e.g., where it difficult to discern which strategies should be used).

Additionally, aspects of the events which are common to a particular strategy or set of strategies should be emphasized by keeping these attributes constant across situations. Aspects of the events not generally relevant to strategy selection should varied across situations.

Feedback will be given by comparing student strategy choices with expert choices, as illustrated through a simulation or video demonstration the implementation of the expert strategy choices (particularly those unique to the sector event).

Standards

Correctly correlate strategies with each type of sector event. For example:

Identify effective strategies for handling conflictions. For example:
- Monitor action to completion
- Monitor separation
- Monitor to vector aircraft
- Monitor to update primary sector plan or implement backup

Identify effective strategies for handling aircraft entering or leaving the sector. For example:
- Evaluate adjacent sectors
- Monitor to start action
- Monitor action to completion
- Monitor to vector aircraft
- Monitor to compare strips with PVD data

NOTE: The above listing of examples represents categories of

strategies, no the specific strategies themselves.

RATIONALE: The vast number of strategies requires some organizational structure for determining when to use which strategies. Sector events provide the ideal organizer for grouping strategies, because ATC is best accomplished with reference to sector events.

OBJECTIVE 7: Relate Monitoring strategies to controller tasks. For each task, identify strategies appropriate for execution of important task subgoals. Identify differences in strategy effectiveness under varying sector conditions.

Conditions/Instructional Methods and Media: Students will be asked to list the key tasks/subgoals for each task, in sequential order (i.e., construct a decision tree). Feedback will be given through comparisons with expert listings. Instructors should explicitly point out the importance of each key subgoal. Students will then be asked to list planning strategies which could be used to implement each key subgoal and identify the optimal strategies for each subgoal. Feedback will be given through comparisons with expert listings. There will also be a class discussion concerning strategies listed by the students which were not listed by the experts, discussing strengths and weaknesses of various strategies. Students will also be shown videos demonstrating or describing the use of different strategies with each key subgoal.

Standards

Identify effective strategies for implementing each key task subgoal, for the following controller tasks:

Resolve Aircraft Conflict.

Reroute Aircraft.

Manage Arrivals.

Manage Departures.

Manage Overflights.

Receive Handoff.

Receive Pointout.

Issue Advisory.

Issue Safety Alert.

RATIONALE: Once strategies have been learned at the event level, they should be practiced at the task level so students can learn the specific conditions under which they are to be implemented. Training should demonstrate the representative range of strategies for implementing task subgoals. This lesson also reinforces previous objectives by initially requiring students to identify key subgoals for each task.

OBJECTIVE 8: Identify and learn to use a range of Workload Management strategies.

Conditions/Instructional Methods and Media: Students will be taught a range of workload management strategies through classroom lecture and video demonstration. Instruction should begin with high-level strategies. Students should then be gradually introduced to the lower-level strategies, with their relationships to the higher-level strategies explicitly pointed out. Similarly, whenever a new strategy is introduced, it should be related to a previously learned strategy (through analogy, contrasts, and comparisons).

Students will then be given workbook exercises in which they must choose the correct planning strategies for specific traffic situations. The exercises should include several situations applicable to each type of strategy or set of strategies, in the following sequence:

1. Prototypical situations (e.g., where it is apparent and clear cut which strategy or set of strategies is to be used).
2. Less clear-cut situations.
3. Borderline cases (e.g., where several different types of strategies are viable).

Additionally, aspects of the situations which are common to a particular strategy or set of strategies should be emphasized by keeping these attributes constant across situations. Aspects of the situation not generally relevant to strategy selection should varied across situations.

Feedback will be given by comparing student strategy choices with expert choices, illustrating through a simulation or video demonstration the implementation of the expert choices.

Standards

Identify appropriate workload management strategies for each control situation.

RATIONALE: In order to introduce students to strategies, they should first be exposed to a range of strategies with accompanying demonstrations. Workload reduction strategies are taught last because their effective use generally requires knowledge of fundamental planning and monitoring strategies.

OBJECTIVE 9: Develop an efficient organizational structure for Workload Management strategies, by grouping strategies according to sector event type.

Conditions/Instructional Methods and Media: Students will first be given a brief lecture on the relationship between strategies and sector event types. Students will then be presented with a series of limited scenarios, with each series showing a particular type of sector event. Students must first identify the sector event and then identify strategies which could be used to handle the event (particularly those unique or especially appropriate to handling the event type).

The scenarios should include situations in the following sequence:

1. Prototypical cases (e.g., where it is apparent and clear cut which strategies should be used).
2. Less clear-cut cases.
3. Borderline cases (e.g., where it difficult to discern which strategies should be used).

Additionally, aspects of the events which are common to a particular strategy or set of strategies should be emphasized by keeping these attributes constant across situations. Aspects of the events not generally relevant to strategy selection should varied across situations.

Feedback will be given by comparing student strategy choices with expert choices, as illustrated through a simulation or video demonstration the implementation of the expert strategy choices (particularly those unique to the sector event).

Standards

Correctly correlate strategies with each type of sector event. For example:

Identify effective strategies for handling conflictions. For example:
- Descend the aircraft to achieve the quickest separation
- Determine action involving minimum coordination
- Determine what to do to eliminate a factor
- Identify aircraft that are not a factor
- Select action that will require least monitoring
- Determine which action can be completed the quickest

NOTE: The above listing of examples represents categories of strategies, no the specific strategies themselves.

RATIONALE: The vast number of strategies requires some organizational structure for determining when to use which strategies. Sector events provide the ideal organizer for grouping strategies, because ATC is best accomplished with reference to sector events.

OBJECTIVE 10: Relate Workload Management strategies to the controller tasks. For each task, identify strategies appropriate for execution of important task subgoals. Identify differences in strategy effectiveness under varying sector conditions.

Conditions/Instructional Methods and Media: Students will be asked to list the key tasks/subgoals for each task, in sequential order (i.e., construct a decision tree). Feedback will be given through comparisons with expert listings. Instructors should explicitly point out the importance of each key subgoal. Students will then be asked to list planning strategies which could be used to implement each key subgoal and identify the optimal strategies for each subgoal. Feedback will be given through comparisons with expert listings. There will also be a class discussion concerning strategies listed by the students which were not listed by the experts, discussing strengths and weaknesses of various strategies. Students will also be shown videos demonstrating or describing the use of different strategies with each key subgoal.

Standards

Identify effective strategies for implementing each key task subgoal, for the following controller tasks:

Resolve Aircraft Conflict.

Reroute Aircraft.

Manage Arrivals.

Manage Departures.

Manage Overflights.

Receive Handoff.

Receive Pointout.

Issue Advisory.

Issue Safety Alert.

RATIONALE: Once strategies have been learned at the event level, they should be practiced at the task level so students can learn the specific conditions under which they are to be implemented. Training should demonstrate the representative range of strategies for implementing task subgoals. This lesson also reinforces previous objectives by initially requiring students to identify key subgoals for each task.

OBJECTIVE 11: Select workload management strategies according to controller workload levels.

Conditions/Instructional Methods and Media: Students will be given a series of scenarios involving the same event types, but the scenarios will gradually increase in workload. Each series should also include the following types of situations:

1. Prototypical cases (e.g., where it is apparent and clear cut which strategies should be used).
2. Less clear-cut cases.
3. Borderline cases (e.g., where it difficult to discern which strategy types should be used).

Additionally, aspects of the events which are common to a particular strategy or set of strategies should be emphasized by keeping these attributes constant across situations. Aspects of the events not generally relevant to strategy selection should varied across situations.

Students will work the scenarios, which will be frozen at various points. At each point, students will be asked which workload management strategies should be employed, if any. Feedback will be provided through comparisons with expert strategy listings, including video demonstrations of their effects (i.e., comparing outcomes when a particular strategy is used versus when it is not).

Standards

Identify effective workload management strategies at each point.

RATIONALE: Once students have mastered workload management strategies, they should be taught how overall workload levels affect their usage.

OBJECTIVE 12: Determine aircraft that are not relevant to the sector events.

Conditions/Instructional Methods and Media: Students will be presented with short scenarios on a CBI system. Each scenario will include aircraft which are not really a part of any sector event and which are generally irrelevant for developing a sector plan. Scenarios will gradually increase in complexity. The scenarios should include situations in the following sequence:

1. Prototypical cases (e.g., where it is apparent and clear cut which aircraft are irrelevant).
2. Less clear-cut cases.
3. Borderline cases (e.g., where it difficult to discern which, if any, aircraft are irrelevant).

Additionally, aspects of the events which are common to determining which aircraft to eliminate as a factor should be emphasized by keeping these attributes constant across situations. Aspects of the events not generally relevant to the determination should varied across situations.

At the start of each scenario, students will be asked to identify present and future events. Feedback will be provided through comparisons with expert grouping and listings. Students must also identify the aircraft which are not relevant to any of the events. Students must then work the scenario twice: first, with all the aircraft present then with the aircraft eliminated (i.e., the aircraft identified as irrelevant). Students will obtain feedback as they compare the ease of controlling the two

scenarios. Feedback will also be provided through expert listings of the irrelevant aircraft, along with video demonstrations illustrating how various aircraft are not relevant to sector planning.

Standards

Identify aircraft which are not relevant to sector events or for overall planning.

RATIONALE: This workload management strategy receives special emphasis in instruction, because this strategy is especially characteristic of expertise (see Redding et al., 1991. Cognitive task analysis of prioritization in air traffic control: Model extension and validation, p. 162-163). As an specific expert-typical strategy, it receives it's emphasis in instruction after the student has first mastered the range of strategies. This lesson also reinforces previous objectives by initially requiring students to group aircraft into sector events.

OBJECTIVE 13: Determine how to expedite aircraft through the sector.

Conditions/Instructional Methods and Media: Students will be given scenarios which will gradually increase in complexity.

The scenarios should include situations in the following sequence:

1. Prototypical cases (e.g., where it is apparent and clear cut which aircraft can be expedited).
2. Less clear-cut cases.
3. Borderline cases (e.g., where it difficult to discern which, if any, aircraft can be expedited).

Additionally, aspects of the situations which are common to determining which aircraft to expedite should be emphasized by keeping these attributes constant across situations. Aspects of the situations not generally relevant to the determination should varied across situations.

Students will work the scenarios, which will be frozen at point(s) when there is an aircraft that can be expedited. Whenever the scenario is frozen, students will be asked whether there are any aircraft which could be expedited through the sector. Students will be asked to develop a short-term plan for expediting the aircraft through the sector, in order to become

part of an event nearing completion. Feedback will be provided through comparisons with expert plans with an accompanying simulation or video demonstration. Students will also be given a simulation or demonstration comparing the effects in terms of sector traffic when the aircraft was expedited through the sector versus when it was not (i.e., no specific plan implemented to expedite its flow).

Standards

Identify aircraft that can be expedited through the sector.

RATIONALE: This workload management strategy receives special emphasis, because this strategy is especially characteristic of expertise (see Redding et al., 1991. Cognitive task analysis of prioritization in air traffic control: Model extension and validation, p. 162-163). As a specific expert-typical strategy, it receives it's emphasis in instruction after the student has first mastered the range of strategies. This lesson also reinforces previous objectives by initially requiring students to group aircraft into sector events.

OBJECTIVE 14: Determine how strategies vary in effectiveness according to different airspace characteristics.

Conditions/Instructional Methods and Media: Students will first be given a brief lecture and/or video demonstration on how differences in airspace features between sectors can affect strategy selection. Students will then be presented with airspace sectors of varying characteristics. First, airspaces should differ with respect to only one characteristic (e.g., en-route structures) with the variation from the first example increasing throughout the series. Then, students should be presented with airspaces differing along two or three characteristics. Finally, students should be presented with airspaces which differ in numerous respects.

Students will be given workbook exercises requiring them to describe how the characteristics of each sector would affect their strategy selection, and compare and contrast the sectors. Importantly, students should identify how the sector airspace characteristic may constrain their strategy selection options. Feedback will be provided through video demonstrations in which the effectiveness of key Planning, Monitoring, and Workload Management strategies are compared across various types of sector airspaces. Students will then be given simple scenarios (of low complexity) in which they control the same traffic situation

across several different airspace types.

Standards

Identify how lateral and vertical limits of key geographical aspects of the sector (sector boundaries, airport locations, NAVAID locations) affect strategy usage.

Identify how key en-route structures affect strategy usage.

Identify how published arrivals, departures, and approach paths affect strategy usage.

Identify how special use airspace affects strategy usage.

Identify how key topography affects strategy usage.

Identify how sector traps or hot spots affect strategy usage.

RATIONALE: Once students have mastered strategy usage, they should be taught how strategy usage may vary depending upon the larger context of the sector airspace. Since strategy usage often is very sector-specific, students need to develop an awareness of these sector-specific concerns through experimentation with various sector airspaces.

BLOCK 5: MONITORING AND SITUATION AWARENESS.

Lesson Goal: Develop adequate situation awareness through use of effective monitoring techniques. Maintain monitoring vigilance and effectively allocate attentional resources.

Time: ----- Days.

Lesson Plan

OBJECTIVE 1: Update the mental model as situational changes (perceptual events) occur.

Conditions/Instructional Methods and Media: Students will be presented with various traffic scenarios, which will gradually increase in complexity and in the number of situational changes that occur. Scenarios will be frozen whenever there is a situational change. Whenever a scenario is frozen, students must describe the current contents of their mental model vis-a-vis the relevant model component. (For example, if the situational change should provide updating information to the aircraft data component of the mental model, students would be asked questions about the current state of aircraft data.) Feedback will be provided through comparisons with expert descriptions/models.

Then, students will be presented with scenarios which are periodically missing some key data necessary for developing an effective long-term control plan. Throughout the practice exercises, it will become less clear-cut as to which key data are missing.

Whenever there is key information missing, the scenarios will be stopped and all displays blanked out. Students must identify the missing data. Feedback will be provided through comparisons with expert descriptions, along with a replay of the relevant portion of the scenario.

Standards

Use new aircraft data from the radar screen to update relevant portions of the mental model.

Use new aircraft data from FPS to update relevant portions of the mental model.

Use automated system messages to update relevant portions of the mental model, including:
- Verbal communication with pilots
- Verbal communication with adjacent controllers.

Identify missing perceptual data.

RATIONALE: Situational changes provide new information irrespective of controller actions. These data-driven events are fundamental to situation awareness, for without adequate awareness of situational changes, controllers cannot effectively develop plans or know when to perform tasks.

OBJECTIVE 2: Update the mental model after execution of each task subgoal.

Conditions/Instructional Methods and Media: Students will be presented with a series of scenarios, each involving a particular task. Scenarios will gradually increase in complexity. Students will be told which task is involved, and asked to work the problem by performing the task until completion. Each time the student completes a key action, the scenario will be frozen and all displays blanked out. Students must then describe the current contents of their mental model vis-a-vis the relevant model component. (For example, if the action should have provided updating information to the aircraft data component of the mental model, students would be asked questions about the current state of aircraft data.) Feedback will be provided through comparisons with expert descriptions/models.

Standards

Correctly describe current traffic situations after execution of key task subgoals/actions for each of the following tasks:

Resolve Aircraft Conflict.

Reroute Aircraft.

Manage Arrivals.

Manage Departures.

Manage Overflights.

Receive Handoff.

Receive Pointout.

Issue Advisory.

Issue Safety Alert.

RATIONALE: Once students have learned situation awareness for data-driven events as reflected through situational changes, students should be taught how to achieve situation awareness for goal-driven events occurring through the implementation of controller tasks.

OBJECTIVE 3: Return to the maintain situation awareness task whenever other tasks are not being executed. Maintain vigilance.

Conditions/Instructional Methods and Media: Students will be presented with scenarios requiring periodic execution of a variety of tasks. The task triggers will be interspersed so that there is some time between tasks (i.e., "rest periods"). These rest periods should vary in length. However, during the "rest periods", various situational changes will occur, some of which should be unexpected.

The scenarios should include situations in the following sequence:

1. Prototypical cases (e.g., where the situational changes are readily apparent and thus do not require significant attentional resources to monitor).
2. Less clear-cut cases.
3. Borderline cases (e.g., where the situational changes are difficult to discern and thus require significant attentional resources).

At various points during each of the "rest periods", the scenario will be stopped and all displays blanked out. Students must answer questions about aspects of the scenario which have changed due to the intervening situational changes (e.g., Did any new aircraft enter the sector? Which ones?). Feedback will be provided through comparison with the actual sector situation, along with guidance as to what monitoring techniques/strategies would have detected the changes.

Standards

Identify situational changes that occurred when controller tasks (other than maintain situation awareness) were not being performed.

RATIONALE: Once students have learned how each individual task can affect situation awareness, students should practice returning to the Maintain Situation Awareness task whenever possible. This task is the central cognitive task of ATC, with this task often trigger another task and with attention frequently flowing back to this task. (See Redding et al., 1991. Cognitive task analysis of prioritization in air traffic control: Model extension and validation, p. 28-29). This task receives special emphasis because it is the central to maintaining situation awareness and is characteristic of expertise.

OBJECTIVE 4: Recall all ongoing events, relevant data on the key aircraft involved, important sector conditions, and the plan for dealing with current sector traffic.

Conditions/Instructional Methods and Media: Students will be presented with scenarios which will gradually increase in complexity. Throughout each scenario, events and situational changes will occur (some of which should be unexpected) more and more rapidly. Scenarios should represent three types of situations, in the following sequence:

1. Prototypical situations (e.g., where the sector events and conditions are apparent and clear-cut).
2. Less clear-cut situations.
3. Borderline situations (e.g., where it may be difficult to discern the sector events and conditions without significant attention).

Students will be asked to work each scenario. At various points during each scenario, the scenario will be stopped and all displays blanked out. At each point, students will be asked questions requiring them to meet each of the standards listed below. Students will also plot the locations of key aircraft on a representation of the PVD. Feedback will be provided through comparison with the actual sector situation, pointing out any discrepancies between the student's description and the actual situation.

Standards

Students will accurately describe:

1. All current sector events.
2. Key aircraft data about the key aircraft in each sector event.
3. Current weather conditions.
4. Current sector conditions (equipment outages, etc.).
5. Effective long-term and short-term sector plans to deal with the current situation.

RATIONALE: Once students have been taught how to maintain situation awareness vis-a-vis individual situational changes and tasks, students should learn to maintain comprehensive situation awareness under conditions of varying complexity and clarity.

OBJECTIVE 5: Maintain comprehensive situation awareness during a critical situation or job bottleneck.

Conditions/Instructional Methods and Media: Students will first be shown several simulations or video demonstrations which present a potential "tunnel vision" situation within a scenario, and which illustrate how the tunnel vision problem could be avoided. Students will then be presented with scenarios which are likely to cause "tunnel vision." During this time, situational changes (some of which should be unexpected) will occur throughout the scenario. Scenarios should increase in complexity and workload, and present situations of increasing criticality.

During various points in each scenario, the scenario will be stopped and all displays blanked out. At each point, students will be asked questions requiring them to meet each of the standards listed below. Feedback will be provided through comparison with the actual sector situation, pointing out any discrepancies between the student's description and the actual situation. Feedback will also be provided by pointing out to students which aspects of the situation they tended to focus on most, and which they tended to ignore.

Standards

Students will accurately describe:

1. All current sector events.

2. Key aircraft data about the key aircraft in each sector event.
3. Current weather conditions.
4. Current sector conditions (equipment outages, etc.).
5. Effective long-term and short-term sector plans to deal with the overall sector situation.

RATIONALE: One of the most important but difficult aspects of effective monitoring is maintaining situation awareness for the sector as a whole when there is an ongoing critical situation in one part of the sector. The tendency is to attend solely to the critical situation, thereby losing awareness of other sector events and situational changes. Controllers call this phenomenon "tunnel vision". Allocating attention effectively during a critical situation is a difficult task requiring a great deal of attentional resources. Thus, this objective is taught after students have first mastered situation awareness during relatively normal sector conditions.

OBJECTIVE 6: Accurately estimate controller workload. Determine when in danger of decreased situation awareness due to work overload.

Conditions/Instructional Methods and Media: First, students will be shown a videotape of someone controlling air traffic, whose performance is degrading due to work overload. Students will be asked to list all the key indicators of work overload. Feedback will be provided through comparisons with an expert listing and a replay of the videotape describing the point at which each critical cue is first present. Students will then be presented with scenarios of varying workloads, as follows:

1. Light workload.
2. Moderate workload.
3. Heavy workload.
4. Work overload.

Students will be videotaped while working the heavy workload and work overload scenarios.

Students will be required to work each scenario, which will be stopped at various points and all displays blanked out. Students will then be required to meet each of the standards listed below. Students will also be given a critical cue checklist, and asked to check-off any of the critical cues which they experienced while working the scenario.

Feedback will be provided through comparing student descriptions with the actual sector situation, pointing out any discrepancies between the descriptions. Additionally, the videotapes will be played back to each student, who will be asked to list his or her own indicators of work overload present in the situations, and to identify the point at which assistance would have been required. When critical cues are present, instructors will point out the relationship between the cues and the student's decreased situation awareness (as might reflected through the student's inability to meet the standards listed above).

Standards

Students will accurately describe:

1. All current sector events.
2. Key aircraft data about the key aircraft in each sector event.
3. Current weather conditions.
4. Current sector conditions (equipment outages, etc.).
5. Effective long-term and short-term sector plans to deal with the overall sector situation.

Student will also identify the:

Presence of any critical cues.

Points of work overload.

RATIONALE: Students must learn how to judge their own workload levels and to recognize cues which indicate that a work overload situation may be developing. Recognition of work overload is crucial for maintaining situation awareness, as work overload results in decreased situation awareness. However, because workload tolerance is to a degree subjective and particular to the individual, students must gauge their own ability to handle various workloads by experimenting with various workload levels. This lesson also reinforces previous objectives by requiring students to describe and recall sector events, conditions, and control plans.

BLOCK 6. DATA VERIFICATION

Lesson Goal: Maintain ongoing situation awareness and avoid decisionmaking and planning biases through proper data verification.

Time: ---- Days.

Lesson Plan

OBJECTIVE 1: Verify key aircraft data for accuracy. Correlate FPS data with radar data.

OBJECTIVE 2: Identify errors in computer entry.

OBJECTIVE 3: Verify readbacks.

OBJECTIVE 4: Project future aircraft routing, and monitor for verification.

OBJECTIVE 5: Project potential future conflictions, and monitor for verification.

OBJECTIVE 6: Project future on-going sector events, and monitor for verification.

OBJECTIVE 7: Develop methods for seeking out disconfirmatory data.

BLOCK 7. WORKLOAD REDUCTION

Lesson Goal: Reduce overall controller workload through appropriate use of general workload reduction techniques.

Time: ----- Days.

Lesson Plan

OBJECTIVE 1: Determine relative priorities among controller activities, under varying conditions.
- Scanning PVD, reviewing FPS.
- Acknowledging pointouts, marking FPS.
- Coordination and communication tasks.

OBJECTIVE 2: Determine situations where appropriate to use computer entry techniques to reduce workload.

OBJECTIVE 3: Determine situations where appropriate to reduce off-frequency communication to reduce workload.

OBJECTIVE 4: Determine situations where appropriate to decrease communication and coordination activities to reduce workload.

OBJECTIVE 5: Determine how and when to take procedural shortcuts.

BLOCK 8. CRITICAL INCIDENT TRAINING

Lesson Goal: Recognize critical situations and controller errors, and develop heuristics and strategies for learning from them.

Time: ----- Days.

Lesson Plan

OBJECTIVE 1: Identify when an abnormal or critical situation is developing.

OBJECTIVE 2: Identify key elements (abnormals) which cause critical situations.

OBJECTIVE 3: Identify decisionmaking and planning biases which cause critical situations.

OBJECTIVE 4: Identify own tendencies for decisionmaking and planning bias under unusual conditions.

OBJECTIVE 5: Develop new, alternative plans to handle critical situations.